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Nutrient Mass Balances and Leaching Losses from a Farmyard Manure Pit in Madhya Pradesh

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The quality of farmyard manure (FYM) prepared by farmers by traditional method is poor due to loss of nutrients during its preparation and low nutrient content of inputs. Earlier studies showed that the groundwater collected from habitation areas contained higher concentration of nitrates than those of field areas which was attributed to movement of nutrients from FYM pits to nearby water sources. But little quantitative data exist on nutrient mass balances or their losses *via* leaching. To address these shortcomings, a study was conducted on a representative, traditional FYM pit in Geelakhedi village, Madhya Pradesh. Cattle dung was the main component of FYM (67%) followed by cattle shed waste (20%); ash, household sweepings, and vegetable waste were minor components. A total of 3700 kg of FYM was produced from the 5760 kg of materials that were put into the pit. Importantly, 39% of the N, 20% of the P and 32% of the K inputs were lost during the preparation of FYM. Nutrients capture on exchange resin cores showed that at least 27% of the N, 30% of the P and 50% of the K were lost through leaching. Further studies are needed to improve accuracy and to determine losses through other mechanisms. Despite nutrient losses, FYM is an important resource that could be even more valuable with reduced nutrient losses.

Key words: Farmyard manure, nutrient balance, leaching losses

In India, farmyard manure (FYM) is an important source of nutrients and organic matter (OM), and is integral part of traditional crop production. Farmers in Central India produce FYM by putting materials such as cattle dung, cattle shed waste, and other waste into pits on a daily basis. Cattle dung is an important by-product of livestock production, being used as FYM, as dung cakes for fuel, or mixed with clay for building purposes. Cattle dung varies greatly in its nutrient value depending on the feed provided to animals and the admixture of other components. Manure from cattle in commercial feedlots in the USA (Wang *et al*. 2011) and Australia (Ghosh *et al.* 2010) had 2% N, 1-5% P and 2-15% K. Studies in India (Reddy *et al*. 2005) and Africa (Zingore *et al*. 2008), by comparison, have shown much lower nutrient concentrations of 1% N, 0.2% P and 1% K in FYM. Composting of animal manure and other organic inputs has been a long-standing practice in traditional farming systems, but many physical, chemical and biological factors need to be optimized to ensure high quality of the end product (Bernal *et al*. 2009).

Heavy rainfall in the monsoon season in Madhya Pradesh precludes the making of dung cakes during this period. Hence, cattle dung along with other materials is taken to manure pit for production of FYM. There is a potential for large nutrient losses because the manure pits, which are generally 1.0-1.5 m deep, are often waterlogged and overflowed. Vigorous weed growth and the presence of algae in the runoff water point to nutrient losses in the runoff. Nutrient losses may also occur through leaching, and N may also be lost through denitrification under the waterlogged conditions.

Both poor animal feed, addition of low-nutrient materials and loss of nutrients contribute to the low quality of FYM produced in Madhya Pradesh, which contains only 0.5-1.0% N, 0.2-0.3% P, and 0.5-1.0% K (Ramesh *et al.* 2009). The leaching loss of nutrients, particularly N, not only reduces the quality of

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FYM but also causes pollution in nearby wells. Many areas in India, including West Delhi have high nitrate-N (NO_3^--N) ranging from 158-1923 mg L^{-1} in groundwater, which is considerably above the WHO desirable and permissible limits of 45 and 100 mg L^{-1} (Adhikary *et al.* 2010). The high concentration of NO_3^--N in village well-water has been attributed to leaching from manure pits into nearby wells (Singh and Sekhon 1977). Biswas *et al*. (2010) conducted survey on nitrate concentration in ground waters of Hoshangabad district of Madhya Pradesh. The highest level of nitrate in open wells, tube wells, and hand pumps were 89, 44 and 25 mg N L^{-1}, respectively. As a whole, the sources from habitation areas are much more polluted (18%) than those from field areas (6%) due to leaching of nitrates from FYM pits.

Nutrient balances have been quantified in developed countries (Sommer and Moller 2000; Bernal *et al*. 2009), often focussing on prevention of eutrophication or emission of greenhouse gases. In developing countries, however, there is no information of nutrient fluxes associated with traditional FYM pits and nutrient losses by leaching. This study, therefore, focussed on the mass balance of nutrients in the material added to FYM pits, *viz*., cattle dung, cattle shed waste, ash, household sweepings, and vegetable waste and leaching losses from a representative traditional FYM pit in Geelakhedi village, Rajgarh district, Madhya Pradesh.

Materials and Methods

Nutrient Inputs and Outputs

The FYM pit of Mr Hukum Singh's household was selected for mass balance studies being representative of those in the village, owning two buffaloes, two bullocks and one young stock. The FYM pit was also typical, being about 1.5 m deep in a Vertisol, the main soil type in much of Central India including Madhya Pradesh. Community workers in the village measured the fresh weight of each type of material (cattle dung, cattle shed waste, ash, household sweepings, and vegetable waste) once a week over 9 months from July 1, 2006 to March 31, 2007, and collected samples for analysis. The moisture in each sample was determined so as to express nutrient values on dry weight basis. The dried samples of each type of material were pooled on a monthly basis to obtain composite samples which were ground prior to nutrient analyses and the total amount of each nutrient in each component calculated.

The FYM was taken out from pit in May 2007 and applied to land prior to growing the soybean crop during the monsoon season. On emptying the FYM pit, the total weight of the field moist FYM produced from the pit was recorded and FYM samples collected for laboratory analyses. The FYM samples were dried and the total dry weight of FYM determined by adjusting for moisture content. The total amounts of nutrients in the FYM were computed and their recovery determined.

Ion Exchange Resin Studies

Resin cores constructed of PVC tubing with 10 cm diameter and 10 cm length contained a combined cation-anion exchange resin mixed with two volumes of acid-washed sand. The mixture was well compacted in the cores (Lehmann *et al*. 2001) and both ends of the cores closed with a wire mesh. Prior to the addition of composting materials, two cores 0.5 m apart were installed vertically into holes in the soil drilled with a ring auger in the bottom of the FYM pit. Other than this, the FYM pit was left undisturbed as is common practice.

When the FYM pit was emptied 9 months later, the resin cores were collected and each core cut into three layers, 0–3, 3–7 and 7–10 cm. The resin collected from each layer was extracted and the extractants analyzed for N, P and K. There was little difference in nutrient concentrations in the three layers, therefore, the mean nutrient concentrations were computed to estimate leaching losses.

Chemical Analyses

Total N was determined by digesting subsamples of organic materials and FYM using a semi-Kjeldahl method (Jackson 1973). Sub-samples of organic materials and FYM were digested in 3:1:1 HNO_3:$HClO_4$:H_2SO_4 mixture for the determination of P and K using the vanadomolybdate yellow colour method and by flame photometer, respectively (Jackson 1973).

Resin sub-samples were extracted with 1 *M* KCl for 2 h on an agitator and the inorganic N (NO_3^- and NH_4^+) in extracts determined photometrically with a continuous flow analyser. Further, sub-samples were extracted with 0.5 *M* $NaHCO_3$ and P determined in the aliquots by the ascorbic acid method. Extraction of resin sub-samples with 1 *M* neutral ammonium acetate was used to determine K by flame photometry.

Computation of Leaching Losses

The bulk density of the FYM was determined by collecting core samples at depths of 0–50, 50–100

Table 1. Quantities of different organic materials put into a traditional FYM pit over a period of nine months in Geelakhedi village, Rajgarh District, Madhya Pradesh

Parameter	Material					
	Cattle dung	Cattle shed waste	Ash	Household waste	Vegetable waste	Total
Dry weight (kg)	3870	1150	590	130	20	5760
Percentage	67	20	10	2	1	100

cm and 100–150 cm. The mean bulk density of the FYM (0.68 g cm^{-3}), was used to compute the weight of the FYM in a core above the resin having 1.5 m height and 10 cm diameter. The weight of dry FYM in this core was 8.0 kg. The N, P and K losses from this core portion of FYM were computed based on the percentage losses of these nutrients from bulk FYM obtained in the mass balance studies. It was assumed that the nutrients from this core of FYM were leached into the resin cores and trapped by the resin. Therefore, the amounts of N, P and K recovered by resin were expressed as percentage of their total loss from the FYM core and this percentage loss of N, P and K being considered as lost by leaching.

Results and Discussion

Mass Balance of FYM

During the 9 months from July 2006 to March 2007, a total of 5760 kg dry matter was added to the FYM pit (Table 1). Cattle dung (67%) and cattle shed waste (20%) made up the greatest proportions, the remainder being ash and household waste. Cattle dung addition to the FYM pit was mostly (65%) during the period July-October because heavy rain during the monsoon precluded the making of dung cakes for fuel.

At the end of the 9 months period, 3700 kg FYM was removed from the pit, which indicated that 64% of the organic materials were recovered in the form of FYM. The 36% dry matter loss in the production of FYM was probably in the form of CO_2. The production of CH_4 (Chang *et al.* 2009), an important greenhouse gas, cannot be discounted given the waterlogging of the pit during the monsoon season. Leaching of organic compounds may have occurred also.

Inputs and Outputs of Nutrients

The N concentration of materials added in the FYM pit ranged from 0.21% for ash to 1.72% for vegetable waste, with cattle dung and shed waste having a concentration of 1% N (Table 2). The cattle dung from animals in Madhya Pradesh was of markedly lower quality than that reported from USA. Comparative data from the study by Wang *et al*. (2011) for feedlot cattle in USA and the current work show: 2.07 *vs* 0.94% N, 5.18 *vs* 0.24% P and 14.9 *vs* 1.26% K. This indicates the low nutrient supply to cattle in India compared to feedlot cattle in USA. Cattle dung contributed the highest amount of N (79%) in the FYM followed by 17% from cattle shed waste.

Of the total 57 kg N added to the FYM pit, only 35 kg was recovered in the FYM indicating a loss of 39% during FYM production. This loss of N was comparable with the losses of N (42–46%) from the composting of intensive beef and dairy manures in turned windrows (Bernal *et al*. 2009). Leaching, volatilization and denitrification might probably be responsible for N loss in the present study.

Cattle dung had the highest P concentration of 0.23% with ash having a P concentration only slightly lower (Table 2). By far the greatest amount of P (80%) was added as cattle dung. The dry FYM contained 0.24% P indicating a loss of about 20% of the P added

Table 2. Nitrogen, P and K contents of different materials used in the production of FYM in a traditional pit over a period of nine months in Geelakhedi village, Rajgarh district, Madhya Pradesh

Nutrient	Material					Total nutrients (kg)	
	Cattle dung	Cattle shed waste	Ash	Household waste	Vegetable waste	Input	Output
N (%)	1.17±0.06 (45.3)*	0.83±0.10 (9.5)	0.21±0.03 (1.2)	0.50±0.10 (0.7)	1.72±0.24 (0.3)	57.0	34.8
P (%)	0.23±0.02 (8.8)	0.09±0.04 (1.1)	0.17±0.03 (1.0)	0.10±0.02 (0.1)	0.21±0.09 (0.1)	11.1	8.9
K (%)	0.98±0.12 (37.5)	1.23±0.09 (14.2)	2.23±0.44 (14.8)	1.37±0.21 (1.8)	1.22±0.31 (0.3)	68.5	46.6

*Figures in parenthesis are total quantities (kg) of nutrients added through various materials

Table 3. Leaching losses of N, P and K from a traditional FYM pit over a period of nine months in Geelakhedi village, Rajgarh district, Madhya Pradesh

Nutrient	Nutrients present in FYM core (g)	Nutrients lost from FYM core (g)	Nutrients recovered on resin (g)	Nutrients lost by leaching (% of total loss)
N	75	30	8.0	27
P	19	4	1.2	30
K	101	32	16.0	50

to the FYM pit. This loss was somewhat surprising given the likely low mobility of P in the leachate.

Of the materials added to the FYM pit, ash had the highest K concentration of 2.23% but the greatest quantity of K came from cattle dung (55%) followed by cattle shed waste (21%) (Table 2). The K concentration in the FYM was 1.26%, with a K output in the dry FYM of 47 kg against an input of 69 kg indicating a loss of 32% in FYM production.

Besides N transformations resulting in losses by volatilization, the losses of nutrients in the production of FYM occurred most likely through leaching or through runoff as evident from the vigorous weed and algal growth.

Leaching Losses of Nutrients

There were considerable losses of nutrients from the 8.0 kg FYM above the resin core (Table 3). Of the 30 g N, 4 g P and 32 g K lost, 8.0 g N, 1.2 g P and 16 g K was recovered in the resin core indicating that about 27% of the N and 50% of the K was leached during FYM production. The additional loss of N may be attributed to volatilization of NH_3 and denitrification. The leaching losses were further confirmed by the analysis of water samples collected from nearby wells of the village during peak rainy season (September 2006) and post-rainy season (December 2006). The concentrations of NO_3-N in water samples of 10 wells were higher (traces to 48 mg L^{-1}) during September 2006 than those (traces to 20 mg L^{-1}) during December 2006.

Leaching loss of P in the current study was similar to that of McDowell and Stewart (2005) who found that 36% of the P in the fresh cattle dung was leached. The 30% of P leached from the FYM pit is likely to be retained in the first few centimetres of soil and would most likely be recovered in the commonly used practice of removing this layer with the compost. This may occur also with K, of which 50% was recovered in the resin.

Many Vertisols around the world have low infiltration rate (1.32-5.19 cm h^{-1}) and hydraulic conductivity (13.32×10^{-6} - 1.65×10^{-4} m s^{-1}). In shallow Vertisols of Madhya Pradesh, however, the presence of sand or gravel layers below 1 m depth ensures that hydraulic conductivity is relatively high (Hati *et al*. 2006). This is of great benefit from crop production point of view, allowing good growth of monsoon crops such as soybean. However, loss of N occurs with the movement of water along pathways of relatively high hydraulic conductivity, increasing the concentration of NO_3^--N in nearby wells (Singh *et al.* 1995; Biswas *et al.* 2010) or loss of N from the system.

The recovery of similar amounts of nutrients from each of the three layers within the resin core indicates that the resin might have reached saturation (equilibrium with the leachate solution). Thus, following an initial period where nutrients were retained on the resin, leachate might have passed unaltered through the resin core. Longer cores, or ones containing a higher proportion of exchange resin, would need to be used to capture all of the leached nutrients. Given this constraint, the resin core results can only be interpreted as showing that at least 27% N, 30% P and 50% K of the total nutrient loss was a result of leaching. Additional nutrient losses might have occurred through surface runoff during the monsoon season, and for N other loss pathways such as denitrification and volatilization may be important. Unfortunately, we are not able to quantify these losses on the basis of the data obtained in this experiment, and further research is needed to quantify losses of these and other nutrients.

Conclusions

The mass balance study showed that the major components of the FYM produced in a typical traditional FYM pit were cattle dung and cattle shed waste which were the major sources of drymatter and nutrients. There was considerable leaching of nutrients, with at least 27% of N, 30% of P and 50% of K lost in this way during the nine months period of FYM preparation. The ion exchange resin study showed that the leaching is an important pathway of nutrient losses from FYM pits, but further work is needed to more accurately quantify the losses and to determine losses *via* volatilization and runoff.

Improving the quality of FYM by reducing nutrient losses holds much promise. It may be worthwhile to consider roofs some kind of shed over the FYM pits to reduce leaching and development of anaerobic conditions. However, ensuring a proper water regime in the pits would require extra work. Additionally, bunds may be constructed to prevent flow of water into the FYM pits.

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